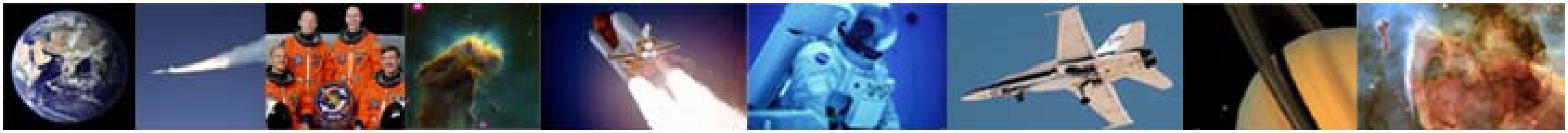

While We Were Sleeping:
The Loss of the Lewis Spacecraft

Leadership ViTS
November 2007

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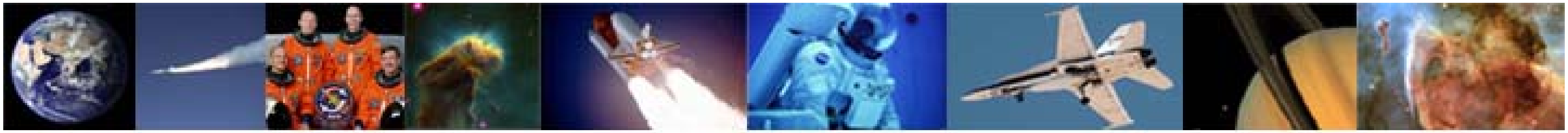


The Failure

- The Lewis Spacecraft program was initiated in the early 1990's under NASA's ***Faster, Better, Cheaper*** (FBC) paradigm. As such, the contract (awarded to TRW) did not include government-specified technical requirements or processes.
- To save money TRW planned to employ only a single shift of flight controllers even for initial on-orbit checkout operations and used a heritage design for the attitude control system (ACS).

Critical Event Timeline (EST)

August 23

2:51 a.m. Launch from Vandenberg AFB to 300km parking orbit.

August 25

10:17 a.m. Contact with the spacecraft is lost for three hours.

1:17 p.m.** Contact reestablished; spacecraft 28° off the Sun; batteries at 43% depth of discharge (DOD). Spacecraft restored to Safe Mode, and observed as stable for four hours. Batteries fully charged.

7:00 p.m.** Mission operations cease; staff begins nine hour rest period, electing not to request emergency backup ops team.

August 26

Early a.m. Autonomous ACS attempts to maintain intermediate axis mode, result in excessive thruster firings and eventual ACS shut-down.

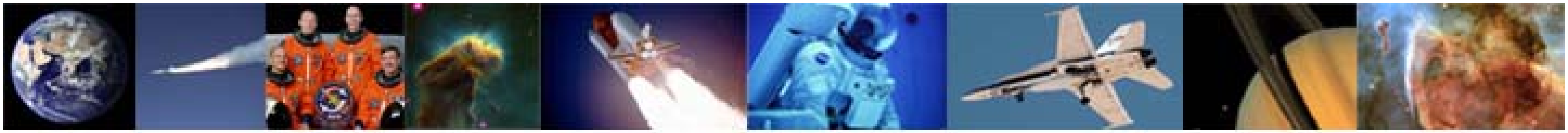
4:02 a.m. Edge-on spin discovered. Batteries at 72% DOD.

6:17 a.m. Mission control attempts to arrest spacecraft rotation by firing ACS thrusters; contact never reestablished.

September 28

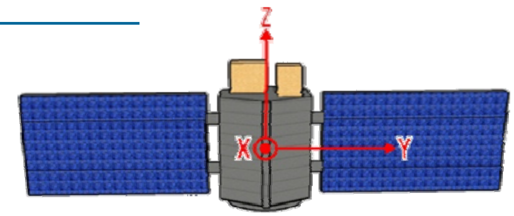
7:58 a.m.** Lewis re-enters earth's atmosphere and burns up.

** estimated time

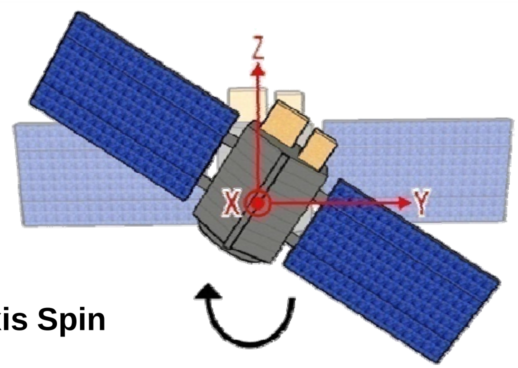


Safe Mode

- During periods of inactivity Lewis used an ACS "Safe Mode" that oriented the face of the solar panels towards the sun about the x-axis, an intermediate/unstable axis. As part of cost saving measures the "Safe Mode" application was re-used from a previous TOMS spacecraft that had a different mass distribution and solar panel arrangement.



Safe Mode

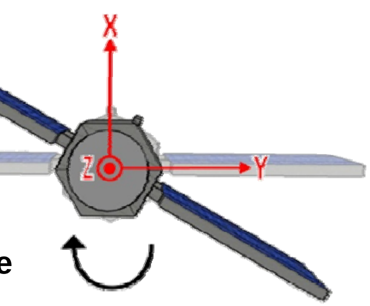


x-axis Spin

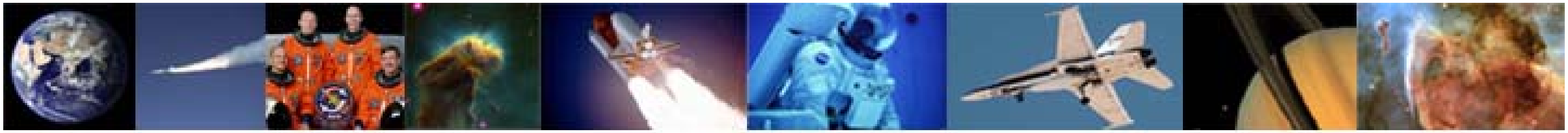
- During an attempt to stabilize the space craft the ACS unexpectedly triggered a spin around the x-axis. The ACS system was controlled by a two-axis gyro that provided no rate information about the x-axis.

- As kinetic energy dissipated, Lewis underwent ***polhode*** motion (multi-axis wobble), slowly migrating from a spin about the x-axis to a spin about the z-axis, the principal axis of inertia. This caused the edges of the solar panels, rather than the faces, to orient towards the sun.

- Unable to maintain a charge on the batteries, the spacecraft shut down, causing loss of control. The spacecraft was eventually destroyed upon reentering the Earth's atmosphere.



polhode

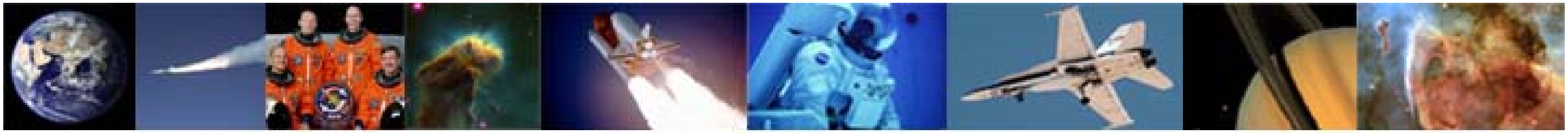


Proximate Causes in Event Chain

- Attitude control system (ACS) failed.
- Inadequate mission operations manning during off-nominal operations.

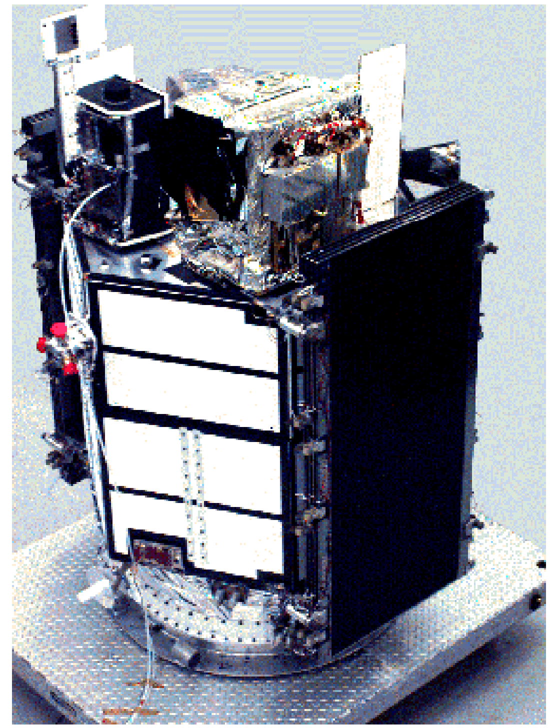
Root causes – Underlying Issues

- Ineffective and inconsistent project leadership:
  - During a single 14 month period TRW saw four different program managers and four General/Division managers.
- Incomplete and unsustained articulation and communication of ***Faster, Better, Cheaper***:
  - By design, there were no government specified technical requirements or processes. FBC relied on commercial best practices rather than traditional NASA management program control functions and there was little government insight to assure best practices were appropriate or even applied.
  - In the absence of higher-level policy guidance, NASA program executives struggled to define FBC in practical terms.
- Inadequate test and verification and peer review of heritage hardware/software:
  - The ACS verification process failed to address the deficiencies that might arise from an improper application of software designed for a much different spacecraft.
  - FBC encouraged the use of heritage hardware and software, but requirements development and validation as well as verification procedures were shallow and often only modeled a limited set of nominal scenarios.
- Insufficient planning to support off-nominal mission operations:
  - Enormous cost containment pressures resulted in an understaffed mission support team that was off-duty at times during key early operational phases. This was compounded by a flawed judgment decision not to activate the emergency backup team.
  - The decision to operate the early on-orbit mission with only a single shift mission control crew was not clearly communicated to senior TRW or NASA management for an opportunity to over-rule an obvious high-risk decision.



Lessons Learned for NASA

- Ensure that schedule and budget goals are realistic and have sufficient margins to accommodate potential modifications or problems.
- Don't compromise system design or mission assurance reviews in the name of consolidation without having confidence in the contractor's processes. There are simply no shortcuts in the fundamental life-cycle systems engineering processes.
- When heritage hardware and software is used make sure its use is well warranted and use cases verified.
- Consistent leadership with senior management involvement and strong communication across the program and project is absolutely essential for mission success.



Reference: Lewis Spacecraft Mission Failure Investigation Board, Final Report , Feb. 12th, 1998.